Lab Manager Approval ______________________ QA/QC Manager Approval ______________________

1.0 PURPOSE AND SCOPE

This procedure describes the methods, materials, equipment, and special conditions required to measure the unconfined compressive strength of cohesive soils. This test is applicable to cohesive soils that will not expel bleed water during the loading portion of the test and which will retain intrinsic strength after removal of confining pressures, such as clays or cemented soils. Dry and crumbly soils, fissured or varved materials, silts peats and sands cannot be tested with this method to obtain valid unconfined compression strength values.

2.0 EQUIPMENT

2.1 BALANCE
The balance must be capable of precision to ± 0.01g.
2.2 COMPRESSION DEVICE
The compression device or loading frame, shall meet the requirements of ASTM D-2166.
2.3 SAMPLE EXTRUDER
The sample extruder shall be capable of extruding the soil core from the sampling tube in the same direction of travel in which the sample entered the tube, with negligible disturbance to the sample.
2.4 DEFORMATION INDICATOR
The deformation indicator shall be capable of measuring to 0.001 inches, and have a travel range of at least 20% of the sample length.
2.5 DIAL CALIPERS
Dial calipers for measuring the length and diameter of the sample, capable of measuring to 1% of the measured dimension.
2.6 TIMER
The timer shall capable of measuring elapsed time to the nearest second.
2.7 LAB COAT, GOGGLES, and GLOVES

3.0 REAGENTS

NA

4.0 DEFINITIONS

4.1 UNCONFINED COMPRESIVE STRENGTH
The unconfined compressive strength is the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test, the unconfined compressive stress is taken as the maximum load per unit area, or the load at 15% axial strain, whichever is secured first during the performance of a test.

5.0 DOCUMENTATION

5.1 FLEXIBLE WALL HYDRAULIC CONDUCTIVITY DATA SHEET F-300
5.2 FLEXIBLE WALL HYDRAULIC CONDUCTIVITY DATA SHEET, page 2, F-300A

6.0 PROCEDURE

6.1 TEST OVERVIEW

Effective porosity is determined by measuring the conductivity of the effluent that has passed through the sample. First, steady state flow must be established, with the conductivity of the natural effluent also at equilibrium. Next the tracer solution is introduced to the inflow port and the conductivity of the effluent is monitored until it reaches equilibrium. Conductivity readings are taken to see if the tracer solution has any effect on the conductivity.

6.2 INITIAL SET-UP
Remove sample from storage and check client ID numbers. Notify supervisor of any ID discrepancies. The sample should be in a liner or sleeve. Loose samples or samples for re-molding will be prepared as detailed in section 6.9. Remove the end caps and inspect the sample ends, and if necessary, trim the ends of the sample to be flush with the ends of the liner.

6.3 Fill in the project and sample information on the data sheet.

6.4 PREPARATION OF EQUIPMENT
6.4.1 Saturate two porous stones by either boiling or placing them in a vessel of water and apply a vacuum to the vessel. Select two filter papers (Whatman #1, or equivalent) and if necessary, trim to the proper diameter.
6.4.2 Loosen the cell bolts and disassemble the permeameter cell. If the bottom pedestal is not the correct diameter, loosen the setscrew on the bottom of the permeameter and replace the pedestal with the correct size.
6.4.3 Flush the inlet and out let lines using a wash bottle.
6.4.4 Select the correct size membrane and membrane stretcher, and mount the membrane on the stretcher and secure by applying a vacuum.

6.5 PREPARATION OF THE SAMPLE
6.5.1 If the sample is in a Shelby tube, cut the ends off the Shelby tube with a hacksaw or tubing cutter. Examine the ends carefully. If the sample appears to be the same at each end, cut about 5 inches off of the bottom of the tube, and cap the ends of the Shelby tube. If the ends are not similar, cut another 5-inch length and examine it. Continue cutting lengths until the sample appears to be homogeneous from one end to the other.
6.5.2 Extrude the sample from the liner or sleeve using the sample extruder. Examine the sample and note any sample anomalies such as differences in color, layering, organic material, etc. Make a visual classification of the soil, and record on the data sheet.
6.5.3 Using a knife, wire saw or spatula, rim the ends of the sample if necessary, and weigh the sample and record the weight on the data sheets. Measure the length and diameter of the sample, in three equally spaced points. Record the length/diameters on the data sheet. Calculate the cross-sectional area of the sample, the sample volume and the bulk density. If the client has not provided the confining pressure, multiply the bulk density (in pounds per cubic foot) times the depth of the sample. Divide this result by 144 to obtain the appropriate confining pressure (in psi).

6.6 ASSEMBLY OF THE TEST CELL
6.6.1 Place one stone on the cell's bottom pedestal, and place one dampened filter paper on top of the stone.
6.6.2 Place the sample on top of the filter paper, and ensure that it is centered on the stone and pedestal. Place the remaining filter paper on top of the sample and place a stone on top of the paper. Place the top platen on top of the porous stone.
6.6.3 Slowly place the membrane stretcher over the sample. Lower the membrane until it is over the bottom pedestal. Using your free hand, release the vacuum on the membrane and roll the membrane off the stretcher. Roll the membrane off the top of the stretcher, and adjust the top platen and stone if necessary.
6.6.4 Using lab shears, trim the membrane so that about 1-2 cm of membrane are above the top platen. Wet your thumb and fingers and roll an O-ring onto the membrane stretcher. Slide the stretcher over the

sample and then roll the O-ring onto the bottom pedestal, to seal the membrane to the bottom pedestal. Repeat this operation on the top platen and roll the excess membrane length over the O-ring.

6.6.5 Attach the outlet lines to the top platen by sliding them into the two holes and ensure that the lines engage the O-rings.

6.6.6 Assemble the cell and tighten the three bolts by hand until they are very tight.

6.6.7 Using the proper cell connector and vent tube, fill the cell with tap water at the "Fill Cell" port on the Trautwein control panel.

6.7 USE OF THE TRAUTWEIN TEST PANELS

6.7.1 Select three consecutive burettes for the test, and ensure that all valves are closed, that there is no pressure on the regulator or burette, and that each burette is full of water. Using the appropriate inlet/outlet (1/8 inch tubing) and cell (1/4 inch tubing) connectors, connect the cell, inlet and outlet ports. Usually, the cell inlet ports are the center two valves on the test cell and these usually have red handles. One of these ports/valves is selected as the inlet port and the other is then used as the inlet drain. The outlet ports are on the outside and usually have black handles. As with the inlet connections, one is selected as the inlet and the other is the drain. Tighten the connector nuts with a wrench until tight.

6.7.2 Using regulator 1, apply a seating pressure of about 1-2 psi to the cell burette. Turn valve 1 to "cell" and valve 2 to "pres." And allow the system to stabilize. Attach drain lines to the unused inlet and outlet ports, and hand tightened the nuts. Open the inlet burette valve and flush the air from the inlet lines and base pedestal. Close the inlet burette line.

6.7.3 Open the outlet burette valve and flush the air from the outlet lines and top platen. Close the outlet burette line.

6.7.4 Raise the cell pressure to 5 psi, and allow the system to stabilize. If this is the maximum confining pressure to be used, consolidation of the sample will not be necessary.

6.7.5 Backpressure saturate the sample by first turning the outlet burette to the "off" position and opening the bridge valve. This will keep the inlet and outlet pressures equal.

6.7.6 With the inlet/outlet and cell burette valves closed, raise the pressure on the inlet/outlet regulator to 15 psi and cell pressure regulator to 20 psi. Simultaneously, open the valves for the inlet, outlet and cell. Monitor the water levels in the burettes and allow the system to equilibrate for several minutes. Close the valves and raise the pressure to 30 and 35 psi respectively. Simultaneously, open the valves for the inlet, outlet and cell. Monitor the water levels in the burettes and allow the system to equilibrate for several minutes. The rate of saturation is dependant on the initial degree of saturation, backpressure level and time. Allow the sample to sit for between 12 and 36 hours.

6.7.7 If necessary, consolidation of the sample is started by closing the inlet/outlet burette valves and opening the inlet/outlet drain valves. The cell valve is closed, and the cell pressure is increased. The amount of increase is based on the final cell pressure. Table 6.1 gives some examples of appropriate consolidation sequences.

Table 6.1, Suggested Consolidation Sequences

Final Cell Pressure (psi)	Iterations	Increase per Iteration (psi)
20	2	10, 10
30	3	10, 10, 10
45	3	10, 15, 20

Set up the inlet/outlet drain lines to flow into a graduated cylinder. Usually, a 10 ml cylinder is sufficient. Start a stopwatch at the same time as the cell valve is opened and monitor the outflow of water. Record the time and volume of outflow on a consolidation data sheet, and plot consolidation on square root of time paper. When t_{90} is reached, calculate t_{100}. The next increment of pressure may be applied after t_{100} is reached.

6.7.8 After the sample is saturated and consolidated, flow measurements may be taken. An appropriate initial hydraulic head is applied to the sample by increasing the inlet pressure. This may be done by either filling the inlet burette to “0” and draining the outlet burette to “25” or by increasing the pressure using the inlet regulator.

Table 6.2 Initial and Final Head Pressures

Sample Type	Initial Head Pressure (cm)	Probable Final Head Pressure (cm)
Fine Sand, Silty Sand, Silt, Clayey Silt, Asphalt	30	30
Clay, Grout	30	100
Concrete	100	100

The pressure applied to the inlet may be increased during the test, if the sample has a low conductivity and the volume changes in the burettes are difficult to read with accuracy.

6.8 USE OF THE “LANDAU” TEST PANELS

6.8.1 Select a set of three ports on either side of the panel. Make sure all valves and selectors are in the closed or off position, including the cross connector at the top of the head pressure and backpressure burettes. Position the test cell on the shelf below the control panel and make the inlet, outlet, drain and cell connections.

6.8.2 Fill the head pressure, backpressure and cell burettes by first opening the valve just above the reservoir. Second, put the drain/fill valve in the fill position. Next, open the valve on the specific burette to be filled. Close all three valves when done.

6.8.3 Apply a seating pressure of 1-2 psi on the sample by turning valve 1 to “CELL” and valve 2 to “PRES.” Use regulator 1 to apply a pressure of 1-2 psi.

6.8.4 Turn valve 5 to “HW” and open the inlet and drain valves on the test cell. This will allow the lines to be flushed of any air bubbles. When the lines are flushed, turn valve 5 to “OFF.”

6.8.5 Turn valve 3 to “TW” and open the inlet and drain valves on the test cell. This will allow the lines to be flushed of any air bubbles. When the lines are flushed, turn valve 3 to “OFF.”

6.9.6 Slowly increase the cell pressure to 5 psi, using regulator 1. Take care to not over pressure the system.

6.8.7 Turn valves 3, 4, 5, and 6 to the “OFF” position. If the pneumatic pressure on the head and tail are to be the same, install a cross-connection between the ports at the top of the head and backpressure burettes. If the burettes are not to be equal, they will be pressurized separately.

6.8.8 Backpressure saturate the sample by first adjusting regulator 2 to 15 psi and regulator 1 to 20 psi. Then turn valve 3 to “TW” and valve 5 to “HW.” Then, simultaneously open valves 2 and 6. Monitor the water levels in the burettes and allow the system to equilibrate for several minutes. Repeat this step at 30 and 35 psi respectively. Monitor the water levels in the burettes and allow the system to equilibrate for several minutes. The rate of saturation is dependant on the initial degree of saturation, backpressure level and time. Allow the sample to sit at for between 12 and 36 hours.

6.8.9 If necessary, consolidation of the sample, is started by closing valve 1 and adjusting the pressure on regulator 1 according to the consolidation sequences shown in Table 6.1. Set up the inlet/outlet drain lines to flow into a graduated cylinder. Usually, a 10 ml cylinder is sufficient. Start a stopwatch at the same time as the cell valve is opened and monitor the outflow of water. Record the time and volume of outflow on a consolidation data sheet, and plot consolidation on square root of time paper. When t_{90} is reached, calculate t_{100}. The next increment of pressure may be applied after t_{100} is reached.

6.8.10 After the sample is saturated and consolidated, flow measurements may be taken. An appropriate initial hydraulic head is applied to the sample by increasing the head pressure. This may be done by either filling the head burette to “0” and draining the backpressure burette to “100” or by increasing the pressure using the regulators.

6.9 RE-MOLDING OF TEST SAMPLES
Test samples that are to be remolded at specified densities are compacted according to the client’s request. They may be remolded to minimum density, tap density, or a percentage of maximum (proctor) density. The methods of compaction and equipment used are to be listed on the data sheet. Generally, samples that are to be tested using a rigid wall device are granular, or free flowing and compact readily to a uniform density. Very little effort is required for most soils.

6.10 HYDRAULIC CONDUCTIVITY MEASUREMENTS
Fill the head pressure burette, and drain the backpressure burette, and record the levels on the data sheet. Open the burette valves and record the time on the data sheet. Record the temperature and the cell burette levels on the data sheet. At the selected elapsed time, record the head and backpressure burette levels, the time, the temperature, and the cell burette levels. Continue taking timed readings until the hydraulic conductivity for four consecutive readings is $\pm$ 25% and the inflow/outflow ratio is within 0.75 to1.25.
6.11 COMPLETING THE TEST
6.11.1 Take down the test by closing all valves on the cell and all valves on the panel. Reduce all regulators to zero. Disconnect the cell from the panel and place it in a sink or tub. Drain the cell water from the cell and remove the bolts. Remove the sample from the cell and lay it on a table.
6.11.2 Cut the membrane form the sample using extreme care. Measure the sample lengths and diameters the same as before the test. Record the data on the data sheet.
6.11.3 Weigh the sample and record the weight. Split the sample in half and examine it for anomalies. Photograph the sample if anomalies are present. Take the moisture content of the sample, using either the entire sample or a portion of it.

7.0 CALCULATIONS

7.1 To calculate moisture content (W):

W = [(wet weight of soil - dry weight of soil) / dry weight of soil)] x 100

7.2. To calculate the bulk density, first calculate the average of the length and diameter by adding them up and dividing by 3. Record the calculated values on the data sheet. Next, using both English and metric units, calculate the cross-sectional area by:

Area = ?r^2

Where r = the average diameter divided by 2. Record the area in metric units on the data sheet. Next, calculate the volume of the sample by multiplying the area in English units by the average sample length, and then divide by 1728 to convert to cubic feet. Divide the sample weight by 453.6 to convert grams to pounds, and then divide the weight by the volume, and record the density in the appropriate box on the data sheet.

7.3 Calculate the elapsed time, in seconds, from the initial reading to the final reading by first calculating the total minutes and multiplying this by 60.

7.4 Calculate the hydraulic conductivity, K, as follows:

$K = (al/2At) \ln (H_1/H_2)$

Where: a = the cross-sectional area of the burette in cm^2
l = the sample length in cm
A = the cross-sectional area of the sample, in cm^2
Ln = the natural log of the ratio of the initial head, H_1 to the final head, H_2
H_1 = at initial time, (outlet burette – inlet burette) x correction factor
H_2 = at initial time, (outlet burette – inlet burette) x correction factor

The correction factor is 1.156 for the Trautwein system, and 0.5613 for the Landau system.

8.0 SAFETY

8.1 EQUIPMENT SAFETY
Prior to each operation of the permeameter, the test operator shall visually inspect the system for leaks, disconnected lines, and defective equipment.
8.2 LAB WEAR
Lab wear including a lab coat, goggles, and gloves should be worn at all times.
8.3 WORK STATION
Keep workstation clean at all times. Wipe any spills to avoid safety hazards.
8.4 HAZARDOUS SAMPLES
Refer to Procedure 02 Rev. 1, CONTROL OF HAZARDOUS WASTE.
8.5 OVEN GLOVES
Use oven gloves when removing samples from oven. The sample pans will be hot.

9.0 CORRECTIVE ACTION

9.1 SPILLED SAMPLE
If a sample is spilled in any process of this procedure, attempt to brush the sample into a pan. It is extremely important to always keep lab surfaces clean in order to recover spilled samples. If the sample cannot be recovered, notify your supervisor.

10.0 REFERENCES

ASTM D-2216, "Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil Aggregate Mixtures", Annual Book of ASTM Standards, American Society of Testing and Materials, Philadelphia, Pennsylvania.

ASTM D-5084, "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, Annual Book of ASTM Standards, American Society of Testing and Materials, West Conshohocken, PA.